Home / Water / Cryosphere

Glacier caves

And inside? Glacier caves

Melting water on a glacier surface collects in small seasonal water streams that erode their bed in the ice, and are called bédières (a French term): in fact, ice is impermeable and does not allow the water to seep in deep. However, glaciers are characterized by a number of fractures that run across the surface. Through these fractures surface water can filter in and flow within the glacier. Liquid water is obviously warmer than the ice it comes into contact with, and determines its melting, creating a system of empty spaces, underground passages, shafts and galleries that are similar to the systems of caves in the rock. The difference is that caves in the rock are created by chemical processes, (dissolving limestone) while ice caves are formed due to a physical process (ice melting). The ice cavities form in all the glaciers that are "warm" enough for water in the liquid state to be present. The formation of ice caves is very rapid, and can be observed, one may say, in "real time" : the cavities form and change during the course of a few weeks or a few days and this offers the opportunity to understand analogous forms that developed, in much longer times, in the rocks. For ice caves to form, ice, which is impermeable, must be broken by fractures that enable water to penetrate deeply and, as it melts the surrounding ice, to widen these fractures giving rise to the formation of shafts and galleries, which may even be several metres in diameter. On the surface, shafts and sinkholes are noted, known as glacier sinkholes or moulins (glacier mills), because the water spins like in a water mill, through which water seeps into the depths of the glacier. Due to the effect of gravity, water tends to follow a way as vertical as possible, creating large shafts and deep gorges in the ice that is fractured due to the enormous tensions that develop within its mass, and flows slowly under the thrust of its own weight. Beyond a certain depth (approximately 150-200 m, and it is equal for all glaciers, independent of their thickness), ice becomes plastic and behaves like an impermeable barrier that prevents water from seeping more deeply in its course : thus horizontal galleries are formed, these are completely flooded and convey water from the sinkholes right to the front where, due to the presence of deep crevasses, it can reach the base of the glacier, and then flow outside through the "mouths" of the glacier, with galleries that can be several metres wide, out of which the turbulent greyish waters of the glacier drainage channels flow. The "mouths" of a glacier often really look like large "mouths", similar to the opening of an oven, from which the toponyms of some of the Alpine glaciers derive (oven is forno in Italian) (The Forni Glacier in the Ortles-Cevedale group, the Forno Glacier in the Bregaglia valley, Switzerland).

The best places to observe glacial sinkholes are the plain areas, far from the areas with crevasses, or along the medial moraines, or on the sides of the glacier. These may be found in all the Alpine glaciers, but only in some cases these reach a size that can be penetrated by man. Large sinkholes may be found, for example, on the Gorner Glacier, on the Mer de Glace and on the Forni Glacier.

Evolution of a cave

A moulin forms in a precise point of the glacier where fractures are favourable, and like whatever is on top of or inside the glacier, it is then slowly dragged downstream by the movement of the ice: next spring a new moulin will form in the same point, and the old moulin, deprived with water, which has been captured by its younger upstream companion, will slowly close, due to the plastic swelling of the ice, till it finally disappears after a few years, while new moulins continue to form further upstream. For this reason moulins are almost always in groups, aligned in a precise direction and always in the same point of the glacier : from upstream, moving downstream, it is possible to observe all the stages of the life of a moulin, from moulin "embryos" that are fractures slightly widened by water, to baby moulins, cylindrical holes with a diameter of only a few centimetres, which are often many metres deep, up to large shafts dozens of metres deep, and a few metres wide, with complex forms, and finally old inactive shafts, fossil and silent, that year after year become inexorably narrower, till they disappear without leaving a trace. We are used to thinking of geological phenomena as processes that are mostly slow, even though inexorable, and it is surprising to see the speed at which glacier caves form, modify, and disappear: when returning, even only few days later, to observe the same moulins, it is possible to note deep changes in shape, size, quantity of water supply, so much that at times one may even doubt one is observing the same structure. In order to study these kinds of cavities therefore it is necessary to mark them with stakes so as to be able to recognize them year after year, and to draw their topographical features, in order to monitor the variations in their shape and depth. In this way, for example, it has been possible to study the moulins of the Forni glacier and to establish that moulins have an average life of at least 6 years, of which the first three are necessary to reach the maximum size and the following years show the progressive decline. In larger glaciers, as in the Svalbard islands, old moulins over 25 years old were observed. In any case, independently from the ice thickness, the maximum depth of ice caves does not exceed 200 m (203 m, to be precise, in Greenland): no cave in fact can exist below this depth, considering the limit of fragile ice.

Caves in the ice and ice in the caves

Many Karst caves, dug into the rock, contain ice inside, in amounts that can be also considered abundant. These must not be confused with ice caves that are formed entirely within the glacier. The mechanisms that lead to the formation of ice in a cave are numerous and very complex. Seasonal ice may form in winter because the water that percolates through the crevices freezes near the openings, where the temperatures of the cave are influenced by the cold external temperature. Larger quantities of ice may form due to the freezing of small surfaces of water, as it has been reported, for example, in some caves in the Northern Grigna mountains, in the Prealps of Lombardy : here the ice is quite ancient and can be dated back to the beginning of industrial activities. In some cases the nearness to a glacier may push glacier ice into the galleries as in the case of the famous Castelguard Cave in North America. In other cases, ice forms due to the accumulation and transformation of snow that falls into the entrance shaft. The study of the ice found in caves, performed in an analogous manner as the study of cores taken from the glaciers, can provide extremely precious information regarding more recent climatic variations.

Speleology in the cold

Since the first explorations on the Alpine glaciers, alpine climbers and experts have observed the spectacular display, which is both fascinating and frightening, of glacial sinkholes. Moulins were seen as bizarre natural anomalies, that drew attention and fear, due to the depth that at times could not be measured, and because of the violence with which the waters seemed to be sucked into the glacier’s stomach: for over a century many wondered about the origin of these structures and the invisible course of water within the glaciers (the first recorded explorations date back to the end of 1800 on the Mer de Glace in France), however it is only since the Eighties that technical progress enabled direct exploration of glacial sinkholes, in safe conditions and relatively easily. And so a new discipline has evolved, glacial speleology, which unites exploring and sports activities and scientific research. Thanks to the work of glaciospeleologists, we now are beginning to understand the mechanisms that give origin to glacial caves and the importance of studying them in order to understand glacier behaviour, and particularly how water circulates inside the glaciers. Many explorations have been performing on the immense and spectacular glaciers in Iceland, Svalbard, Patagonia and Greenland (it was here, in 1998, that a glacial lake was found at a depth of 203 m on the bottom of the spectacular moulin in the Malik ice-cave , the deepest ever to be explored), but since a few years even the most modest Alpine glaciers are drawing greater interest, specially due to the possibility of carrying out repeated studies over a number of years. Every year, during a short season, that stretches from late spring to the first autumn snowfall, the main moulins are descended, photographed, measured, marked with stakes, in order to capture, in the variations that are monitored, some elements that might enable a better comprehension of their future formation and evolution. Besides scientific research, which is still at the very beginning, what makes this discipline particularly stimulating for those who practice it, is that the descent in a moulin is one of the most thrilling experiences the mountain can offer, and surely is one of the last exploration frontiers. Because of the water, only the moulins and a small part of the cavity front are practicable, while the rest of the system remains inaccessible for direct explorations: only hypothesis may be made about the structure, using particular methods, as for example, sending coloured tracers inside. The horizontal caves that open on the glacier fronts, that apparently do not involve risks and do not seem to require particular precautions and equipment are explored : often, in fact, these are large environments where it is possible to walk on the rock substratum. Actually it is not advisable to venture into these environments as they are structures that are subjected to the enormous thrust of the glacier mass, and can be extremely unstable. The collapses of blocks of ice and stones, falling from the surface above, are frequent, specially during the warmer hours. Therefore if there are no precise indications or a guide of the place, it is advisable to admire these cavities from a distance. Instead, notwithstanding appearances, exploring glacial sinkholes is less dangerous, on the condition, of course, that you have suitable equipment and a sound technical know-how. In this case the usual techniques for climbing on vertical ice are not adopted (such as piolet traction), but a mix of mountain climbing and caving is used. In fact climbers go up and down hanging on ropes, like those used by cavers, with equipment that is typically used for exploring caves, while the tools derived from mountain climbing are the tubular ice pitons, crampons and a short ice-axe, that facilitate vertical climbing and also movement when the bottom is reached. The risks are connected with water, which flows from outside with a remarkable flow into the active sinkholes and the stones that at times impend over the edges. For these reasons it is opportune to carefully choose the period of the year and the time of the day, when planning a descent, in order to minimize the risks and make this spectacular activity as safe as possible.

Studying ice caves

The entire glacier body moves continuously downstream and in this movement it drags whatever is on its surface and inside. Therefore also the ice cave systems move downward together with the glacier in which they have formed. By studying the mechanisms by which these cavities form, it has been possible to observe that a new sinkhole forms every year in the same point of the glacier, above a fixed point of the substratum. It is as if in that point there were particular conditions, due, for example, to the characteristics of the substratum, that determine the formation of a moulin in the ice that is in that point at that time. The same occurs in the case of whirlpools and eddies in the current of a stream of water : the shape of the whirlpool is always the same, and also the point in which it forms, but the water that forms the whirlpool is continually replaced. For this reason, even though they vary continuosly, glacial caves are stable structures inside a glacier. The distance separating a new sinkhole from the one that formed the previous year, therefore, is equal to the speed of the glacier's downward movement: measuring the distance between aligned moulins is therefore an excellent and rapid system to evaluate the speed of a glacier. And by observing aligned moulins from the top of the mountain to the valley, it has been observed that the speed is not the same for the entire glacier, but it is as if within the body of the glacier there are areas flowing with different flows, that may be more or less rapid : the distances between moulins belonging to the same alignment enable a "visual" evaluation, and do not require complex measurements, the areas that are faster are where the moulins are further apart one from the other, and the slower areas are where the moulins are to be found closer together.